National Bureau of Standards

TECHNICAL NEWS BULLETIN

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NBS Magnetic Compton Spectrometer

ACCURATE ANALYSIS of X-rays having energies between 0.2 and 12 million electron volts is made possible by a new spectrometer developed by the National Bureau of Standards. The magnetic Compton spectrometer, designed and constructed under the direction of Drs. H. O. Wyckoff, J. W. Motz, and W. Miller of the NBS radiation physics laboratory, operates in an energy range that bridges the gap left by other types of X-ray spectrometers. The data obtained with the spectrometer are used in studies of the X-ray absorption properties of various materials. It is expected that the spectrometer will also provide information leading to a better understanding of the nature of X-ray production.

The X-ray intensities and energies measured by the NBS magnetic Compton spectrometer are used in a determination of the amount of shielding required for protection against the dangerous radiations from high voltage machines and nuclear reactors. The Compton spectrometer was used in an analysis of the gamma-rays emitted from a U^{235} slug at the center of the Los Alamos water boiler and from the core of the "fast reactor." The results included a determination of the total energy release of gamma radiation from the U^{235} slug and the gamma-ray spectra from both reactors. The spectrometer also has been used to determine the X-ray spectrum from the Naval Ordnance Laboratory 11–Mev betatron.

The NBS magnetic Compton spectrometer consists essentially of an evacuated chamber composed of the wedge-shaped pole faces of an electromagnet. A collimated beam of X-rays is made to impinge on a window of beryllium foil. As a result of the interaction of the X-rays with the foil material, electrons are ejected from the foil with an energy and angular distribution dependent upon the energy of the incident photons. Only those electrons that are contained within a small solid angle in the forward direction of the beam are focused on a detector-counter by the magnetic field between the pole faces. The X-ray intensity and energy is then computed from measurements of the magnetic field and of the number of electrons striking the detector.

The pole faces and the window through which the incident photons are admitted are arranged so that the magnetic field is perpendicular to the direction of travel. The incident collimated radiation enters the evacuated chamber through an aluminum window. Auxiliary permanent magnets remove stray electrons produced in the aluminium window by the X-ray beam. The beryllium foil is located directly behind the aluminum window. As the X-ray beam impinges on the foil, electrons and positrons are ejected in all directions. The higher the energy of the incident photon, the greater is the concentration of the ejected particles in the forward direction.

The spectrometer is provided with a system of baffles so that only electrons ejected within certain angular limits are detected. The combined effect of the baffles and magnetic field is to focus the electron beam so that it can be detected by a scintillation counter. The magnetic field, measured by a rotating element and a fluxmeter, can be adjusted to known values. Knowledge of the magnetic field, the number of electrons striking the counter per unit time, and the solid angle through which they travel is sufficient information for computation of the intensity and energy of the incident X-radiation.

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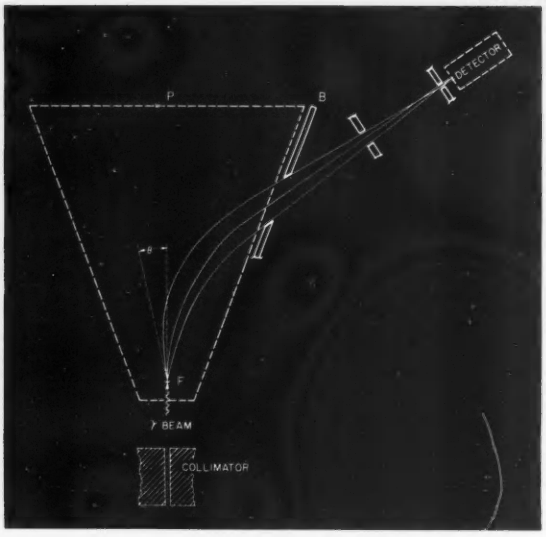
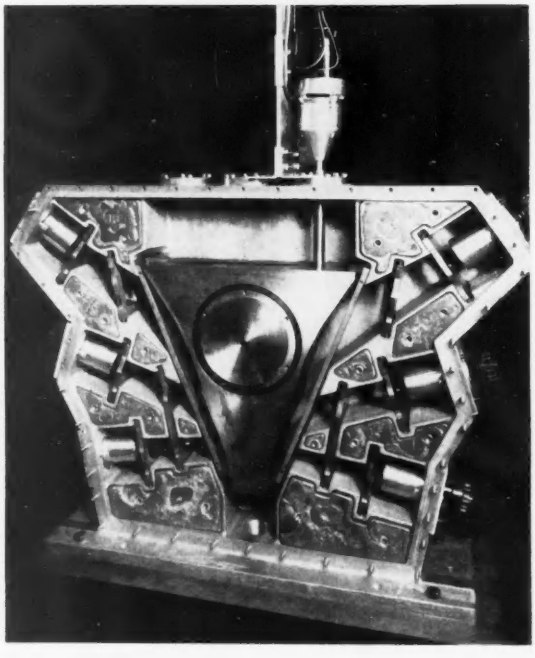


Schematic diagram of NBS magnetic Compton spectrometer. Collimated X-ray beam impinges on beryllium foil *F*. Those electrons contained in small solid angle θ in forward direction of beam are focussed at detector (right) by wedge-shaped pole faces *P*. Baffle *B* may be adjusted to further restrict the angle of acceptance.

The calculations required for a determination of the X-ray energies and intensities apply only to the electrons produced in the Compton process. At energies above 2 Mev, corrections to the measured counting rate must be made to account for the pair-production electrons, which are also ejected from the foil and detected along with the Compton electrons. Such a correction can be made at a given magnetic field strength by reversal of the field and measurement of the number of positrons.

The X-ray intensities and energies are determined on the basis of calibration measurements made with the gamma rays from a 10-curie source of Cs^{137} (0.661-Mev gamma rays) and a 1-curie source of Na^{24} (1.37 and 2.76 Mev). The effect of electron scattering in the beryllium foil and the geometry effect introduced by the foil width and length have been evaluated from studies of the line shapes obtained from different foil sizes when monoenergetic photons of the radioactive materials were incident on the foil. The absolute intensity of the collimated gamma-ray beam for each source was measured with an ionization chamber, and



Inside view of NBS magnetic Compton spectrometer. Collimated beam of X-rays impinges on beryllium foil placed inside the narrow end of wedge-shaped pole pieces. Ejected electrons leave foil at an angle and at an energy dependent on incident radiation. Combined effect of lead baffles and magnetic field is to focus electron beam so as to strike scintillation counter (at exit ports of aluminum chamber). Motor at top of spectrometer and rod extending into space between pole faces is part of fluxmeter used to adjust the magnetic field. Channels for each scintillation counter are shielded from each other by lead inserts.

TECHNICAL NEWS BULLETIN

U. S. DEPARTMENT OF COMMERCE

CHARLES SAWYER, *Secretary*

NATIONAL BUREAU OF STANDARDS

A. V. ASTIN, *Director*

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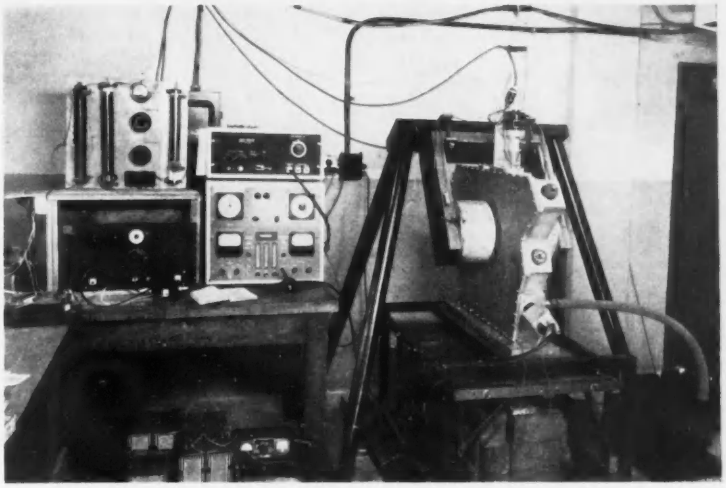


Experimental arrangement for determining the intensity and energy of X-radiation with the NBS magnetic Compton spectrometer. The spectrometer (right) is placed over a source of X-rays (surrounded by lead blocks). The yoke-mounted coils at each side of the spectrometer supply the magnetic field that guides the electrons between the pole faces. The whole system is evacuated by the pump at the far right. The electronic apparatus on the left is the auxiliary equipment required for the detectors and the electromagnet.

the measured values agreed within 5 percent with the values computed from the spectrometer measurements.

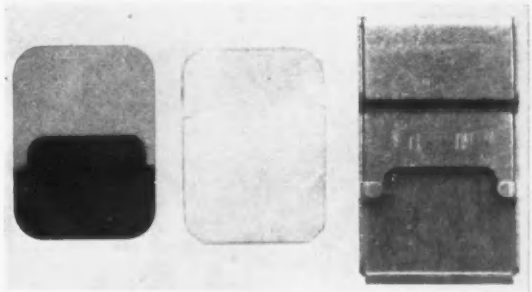
One of the significant factors in the performance of the NBS magnetic Compton spectrometer is the small acceptance angle of the spectrometer baffle. Because of this small angle the Compton electron energy can be related uniquely to the incident photon energy. Another significant factor concerns the detection sensitivity of the spectrometer. Achievement of a reasonably good counting rate with a small beryllium foil requires relatively high X-ray intensities. The resolution of the spectrometer, as determined by the 10-curie cesium source, can be varied from 3 to 30 percent by alteration of the geometry and the foil size.

Film Dosimetry of Electrons

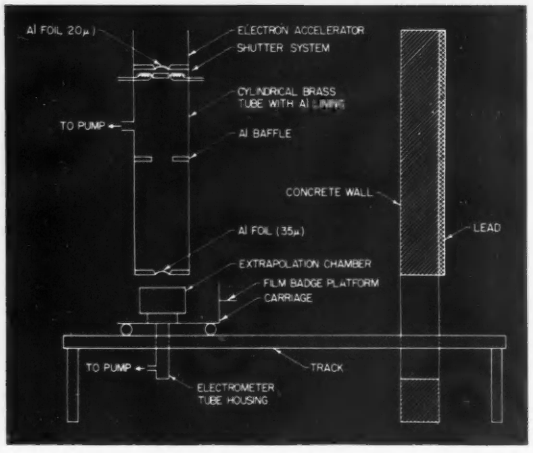
IN AN EFFORT to protect personnel exposed to electrons, NBS has determined the response characteristics of two film types suitable for monitoring these radiations. The response of the two films, Minimax Dental X-ray Film Extra Fast and du Pont Dosimeter type 552 single film packet, when exposed to electrons in the energy range of 0.5 to 1.4 Mev, was found to be linearly proportional to the dosage received and independent of the energy of the incident electrons. The investigation was conducted under the sponsorship of the Atomic Energy Commission.

The increasing use of radioactive materials in research laboratories and industry has intensified the need for simple and inexpensive personnel monitors. The techniques and equipment developed for X-ray monitoring have proved to be valuable guides, but most of the instruments cannot readily be adapted to the measurement of radiation doses from beta-rays or electrons. One of the difficulties is the relatively short range of low and moderate energy electrons as compared to the range of gamma rays of the same energy. The usual gamma-ray monitor requires a wall thickness that, while satisfactory for X-ray dosimetry, stops or materially alters the energy and angular distribution of the electrons before they can reach the sensing element. Radiation film dosimetry is sufficiently accurate if the thickness of the film is less than the range of the electrons (accuracies between 15 and 30 percent are adequate for personnel monitoring).

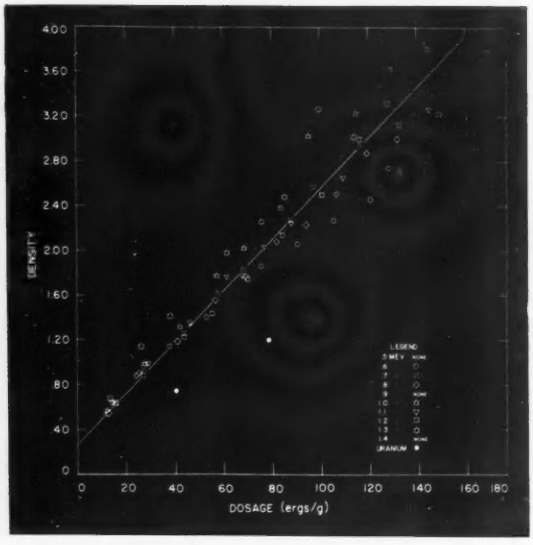
In film dosimeters the opacity of the processed film serves as a measure of the radiation dose to which the film has been previously exposed. For practical purposes each type of film requires its own calibration curve which relates the darkening of the film to the radiation exposure. Such calibration curves have been obtained by the Bureau for the Minimax dental and the du Pont dosimeter films for electrons in the energy range of 0.5 to 1.4 Mev. The electron dosage was



Sample film badge investigated by NBS for film response to electrons. The film at the left has been exposed. The center film is wrapped in layers of paper that tend to attenuate a portion of the electron energy. The metal pack at the right is the film holder.



Above: **Schematic diagram of apparatus used in determination of response of dosimeter films to electrons. Monoenergetic electrons are accelerated in evacuated vertical tube 30 feet high (upper left). Electrons are passed into evacuated collimator and then into extrapolation chamber (left). Carriage supports ionization chamber and film-badge holder. Amount of ionization resulting from electrons entering chamber is measured by FP–54 electrometer tube (lower left). Concrete and lead wall (right) protects experimenters from stray radiation.** ***Below:*** **Density-dose curves for Minimax Dental Film Extra Fast as determined by NBS. Experiments were conducted on response of this film to electrons in energy range between 0.5 and 1.4 Mev and to beta rays from uranium. Graph shows that, within this energy range, response of film is linearly proportional to dose received and independent of energy of incident electrons. A moderate dependence on electron energy is, however, indicated for beta rays from uranium.**



measured in terms of the energy absorbed from the electron beam per gram of absorber.

The voltages necessary to accelerate the high energy electrons required for the NBS investigation are obtained from a generator capable of delivering 1,400,000 volts. Monoenergetic electrons are accelerated in an evacuated vertical tube 30 feet high. The electrons are passed in to an evacuated collimator and then into an extrapolation-type ionization chamber. The chamber is used for calibration of the film darkening against actual dosage from the electron beam in terms of the energy dissipated by the beam incident on a polystyrene disk.

The electron beam is extracted from the accelerator through an aluminum window 0.02 mm thick. In the collimator, an evacuated cylindrical brass tube lined with aluminum, the electrons are directed through aluminum baffles that reduce the amount of scattered radiation incident on the film or ionization chamber and make the main electron beam parallel. A shutter near the entrance to the collimator permits accurate control of the electron exposure time. The electrons leave the collimator through another aluminum window and impinge on the extrapolation chamber or on the film. A carriage supports both the film-badge holder and the ionization instruments so that each can be accurately positioned in the electron beam.

The extrapolation-type ionization chamber is a cylinder with a polystyrene top separable by known increments of height from another polystyrene disk at the base. Polystyrene was chosen because it has an average atomic number and density close to that of human tissue. The upper disk is 7 mg/cm^2 thick, which compares to the thickness of the layer of dead skin covering the human body. Because the body highly attenuates the radiation from commonly available electron sources, the dose received just below this skin depth is the most important.

The opposing surfaces of the polystyrene disks are coated with thin layers of graphite, forming conducting electrodes. The lower electrode, or collector plate, is connected to a rod and a phosphor brass spring which rests on the grid of an FP–54 electrometer tube. The electrometer measures the voltage drop across a high resistance, from which the ionization current at the collector plate is determined.

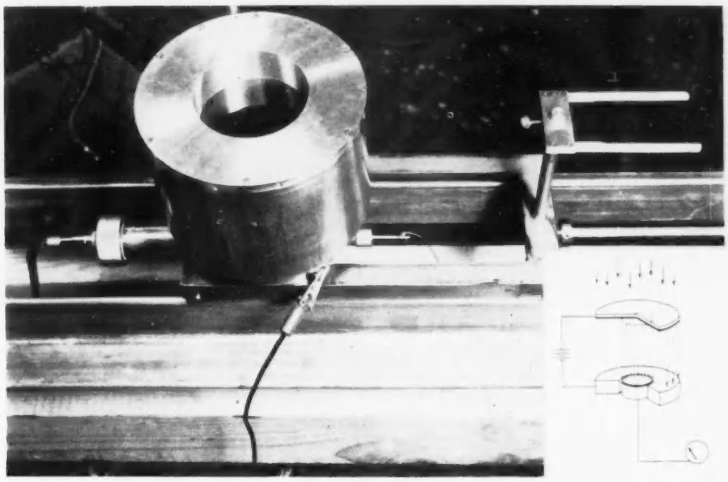
As the electron beam strikes the upper electrode, its intensity is reduced by the absorption of the polystyrene. The attenuated beam produces ionization in the air-filled central volume of the chamber; and an electric field collects the ions at the second electrode, changing its potential. The rate of change of the ion current with respect to the electrode separation, at small separations, is then proportional to the electron dose rate.

The procedure for determining the response of a film packet (a strip of film wrapped in two layers of paper) involves exposure of a measurable number of electrons to the extrapolation chamber and then substitution of the film packet for the chamber with all other conditions unchanged. Data are obtained at each 0.1 Mev in the 0.5 to 1.4 Mev energy range. The electron dose rate

is first determined at a given accelerating potential by the ionization chamber, and then the film is exposed to different doses by timing the exposures. Ionization measurements with the chamber are repeated after the films are exposed to determine the constancy of the dose rate.

Exposures were also made on a uranium plaque with the film placed directly on the tight 7-mg/cm^2 covering of the plaque. The dosage rate of the uranium sample had previously been measured by the AEC to be 20.1 (ergs/g)/hour at the surface of the covering.

All films exposed at a given energy are processed simultaneously with a control film. They are developed for 5 minutes in Eastman Liquid X-ray Developer and Replenisher at 20°C, fixed for 5 minutes at 20°C, washed for 30 minutes, and dried. Film density is determined on a calibrated Ansco-Sweet densitometer, model 11, for densities below 2.5 and on an Ansco color densitometer, model 12, for higher densities.



Extrapolation-type ionization chamber used in determination of response of personnel monitoring films to electrons of 0.5 to 1.4 Mev energies. Electrons are directed to chamber from collimator and fall on polystyrene disk of about same density, atomic number, and thickness as human tissue. Undersurface of polystyrene is coated with thin layer of graphite, forming conducting electrode. Lower electrode, or collector plate, is separated from upper disk a distance that may be varied by known increments. Chamber is mounted on movable carriage. ***Inset:*** **Schematic diagram of chamber. As electron beam strikes upper electrode, its intensity is reduced by absorption of polystyrene. Attenuated beam produces ionization in air-filled central volume of chamber; and electric field collects ions at second electrode, changing its potential. FP–54 electrometer detects ion current.**

It has been recommended by the International Congress on Radiological Units (London, 1950) that electron dose be expressed in ergs absorbed per gram of tissue at the point in question. Thus, the ionization current was plotted as a function of plate separation (in the extrapolation chamber). The slope of the curve together with the area of the collecting electrode yielded ionization current per unit volume in the air of the ion chamber. From this information the energy absorbed per unit mass of polystyrene (the tissue-equivalent material) was computed.

The results of the NBS investigation are presented as a graph of film density versus dose (ergs/g) with the various values of the incident energy of the electrons as parameters. The density-dose relationship of the uranium plaque is also included on the plot. The data of the monoenergetic electrons indicate that, within the accuracy of the films, the response of the film is independent of the electron energy in this range.

The density-dose characteristic for the films exposed to the uranium beta rays indicates an energy dependence between the monoenergetic electrons and the beta rays from the uranium. The calculated most probable energy from the complex beta spectrum from the uranium is approximately 0.1 Mev with the average energy near 0.45 Mev. Because the film is wrapped in paper with a total thickness of about 25 mg/cm^2, about 22 percent of the beta rays are absorbed in the paper covering before the rays reach the film. From the distribution of experimental points for the monoenergetic electrons there is an indication that a much smaller fraction of the monoenergetic electrons are absorbed in the paper. Thus, the beta-ray energy dependence appears, in part at least, to be due to the absorption in the paper covering.

For most personnel monitoring dosimeters using film as the sensing element the curves developed by NBS for these two film types will suffice as a means for checking the electron dose. At a minimum the information that should be known is the energy range of the electrons (between 0.5 and 1.4 Mev for these curves to be valid). The procedures outlined for developing the film should be followed, and the density of the film should be measured on the indicated or similar densitometers. A step wedge filter incorporated in the film packet could be used to provide qualitative information as to the electron energy. A plot of film density against filter thickness would then permit an extrapolation to a filter thickness of 7 mg/cm^2. Because the thinnest filter would have to be quite thick in order to make the packet light-tight and because determination of electron energy spectrum from an attenuation curve gives only an approximate answer, the proposed filter would not yield a high degree of accuracy. However, in many cases it would be sufficient for personnel monitoring.

For further technical details, see Film dosimetry of electrons in the energy range 0.5 to 1.4 million electron volts, *by J. Fleeman and F. S. Frantz, J. Research NBS* **48,** *No. 2, 117 (February 1952).*

Effects of Tannage on the Properties of Leather

SPECIFIC information regarding the effects of different tannages on the properties of leather has recently been obtained by Dr. J. R. Kanagy and associates of NBS in research sponsored by the Office of the Quartermaster General. Leathers tanned with chrome alone were compared with those tanned first with chrome and then retanned with vegetable tannins. The results in general indicate that each of the two types of leather has certain definite advantages and that choice of tannage should depend largely on the properties desired in the finished leather.

Both methods of tanning are widely employed in the leather industry. In general, the more rapid chrome-tanning is now used chiefly for lighter leathers such as calfskin shoe uppers and kidskins for gloves while the two-step process is used for heavier leathers, such as soles, belting, and heavy uppers. The Army requested the Bureau to make an objective study of the characteristics of the two types of leather as part of a program to provide improved footwear for the armed forces.

The NBS investigation included physical tests of such properties as tensile, stitch-tearing, tongue-tearing, and bursting strengths. Water resistance and water-vapor permeability were also determined; and chemical analyses were made for hide substance, grease content, chromic oxide, and ash. Vegetable tannin content was obtained by difference. To eliminate the effect of variations due to the part of the hide from which the leather was taken, each property was determined from samples taken from 21 different sections over a side of leather.

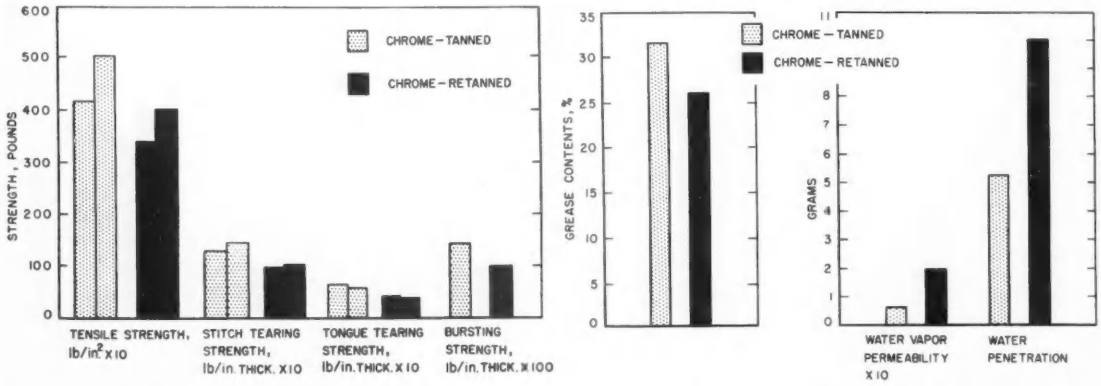
The test results showed that vegetable tannins tend to decrease water resistance, reduce strength, and increase thickness. However, on the whole the properties produced by use of the vegetable tannins tend to make the leather more comfortable for shoes and to increase cutting value (percentage of useable hide).

To learn more about the factors producing these effects, NBS made density determinations. For a variable material having a porous matrix, such as leather, the density in any particular location can be expected to bear a definite relationship to the amount of fibrous material at that point, which in turn is related to the strength and other physical properties.

Although the retanned leathers contained about 20 percent of vegetable tanning material in addition to an amount of chromic oxide approximately equivalent to that held by the straight chrome leather, the average density of the retanned leather was no greater than that of the chrome leather. Thus a volume change must have occurred in the chrome-retanned leather. This volume change is reflected not only in the lower strength of the chrome-retanned leather, which obviously must contain less fibrous material per unit volume, but also in more uniform thickness and consequently greater cutting values.

Apparently the introduction of vegetable tannins into the leather resulted in a more hydrophylic material, as evidenced by the lower water resistance and greater water-vapor permeability of the retanned leather. Another result of the introduction of vegetable tannins was an increase in the amount of grease absorbed by the leather. This effect was to be expected since the vegetable tannins are composed of larger molecules than the chrome compounds used in tanning and are thus more effective in filling the pores in the untanned leather. Consequently, less space remains to be filled with grease.

For further technical details, see Variation of physical and chemical properties within and between vegetable-retanned cow and steer hides, *by J. R. Kanagy, E. B. Randall, Jr., T. J. Carter, R. A. Kinmonth, Jr., and C. W. Mann, J. Am. Leather Chem. Assoc.* **47**, 726 (1952).



Left: **Graphical comparison of strength properties of chrome-retanned leather with those of leather tanned with chrome alone. In each pair of blocks, left block represents value of hide property measured perpendicular to backbone of animal while right block shows corresponding value parallel to backbone.** ***Right:*** **Comparison of chrome-tanned and chrome-retanned leathers in regard to grease content (left) and water vapor permeability and liquid water penetration (right). Water vapor permeability is measured in terms of number of grams of water which penetrate an area of 25 cm² in 100 minutes. Water penetration is given as number of grams absorbed by a wick in a given time.**

A Spectrophotometric Standard for the Ultraviolet

A SATISFACTORY spectrophotometric standard for the ultraviolet region is now available as the result of an extensive investigation conducted by Geraldine W. Haupt of the National Bureau of Standards. The standard consists of an alkaline solution of potassium chromate which may be readily prepared in any laboratory from the composition specified by the Bureau. Calibration data provided by NBS will enable users of spectrophotometers in the ultraviolet to check the reliability of the instrument's photometric scale and to detect important errors resulting from wavelength inaccuracies, stray light, or excessive slit widths.

The spectrophotometer has long been recognized as a valuable instrument for color analysis, chemical analysis, determination of structure, detection of impurities, and determination of ionization constants and rates of reaction. At first its use was confined almost entirely to laboratories engaged in basic research. However, with the development of commercial photoelectric models—direct-reading, rapid to use, and often automatically operated—the spectrophotometer found widespread application in industrial laboratories, and thousands are now in daily use in both research and control.

Experience has shown that spectrophotometers may need frequent comparison with a set of standards to assure their reliability. Although repeated trials may provide data of high reproducibility, gross errors in wavelength may nevertheless make the values that are obtained highly unreliable if the instrument has not been recently checked. The Bureau therefore began issuing glass spectrophotometric standards of various kinds in the 1930's, primarily to cover the visible range of the spectrum, which is of major interest in colorimetry. Then, about 1940, photoelectric spectrophotometers covering the ultraviolet as well as the visible spectral regions appeared on the market, and standards for the ultraviolet became necessary. Because glasses are unsuitable for standardization in the ultraviolet from the standpoint of both permanence and type of transmittance, the Bureau undertook to study some other type of material.

In view of the high transmission of distilled water in the ultraviolet, it appeared that an aqueous solution of some inorganic salt would be most suitable. Such a solution would also have the advantage over glass that it could be prepared from specifications in whatever laboratory the standard was to be used. After several years of work, the necessary spectrophotometric measurements were completed on an alkaline solution of potassium chromate at 25° C over the wavelength range from 220 to 500 millimicrons.

The potassium chromate solutions studied were prepared in two ways: One starting with potassium chromate (K_2CrO_4), the other with potassium dichromate ($K_2Cr_2O_7$). The first type of solution requires 0.0400 gram of K_2CrO_4, reagent grade, per liter in 0.05 normal potassium hydroxide. The second type of solution has the same concentration and alkalinity as the first but is prepared from 0.0303 gram of $K_2Cr_2O_7$ per liter; when neutralized by the KOH, this quantity of potassium dichromate gives 0.0400 gram of K_2CrO_4 per liter and thus provides an identical solution. However, there is usually a distinct advantage in using potassium dichromate as one of the reagents because in stock material potassium dichromate exists in a purer state.

To provide calibration data for the potassium chromate standard, NBS made extensive measurements of the spectral transmittancy of the solution (0.0400 g of K_2CrO_4 per liter in 0.05 normal KOH).

The solutions were measured on five types of spectrophotometers by three different methods. One of the instruments makes use of a photographic method, operating primarily in the ultraviolet but also to some extent in the violet and blue; another employs a visual method; and the remaining three are photoelectric. The final values for the ultraviolet region were derived from a large number of measurements with three different types of instruments. Values of spectral transmittancy T_s, for 1.000 cm thickness of solution were obtained over the range studied; and from these data values of absorbancy, $A_s (= -\log_{10} T_s)$, were computed. Computations were also made giving values of spectral transmittancy for 2.000 cm thickness and values of molar absorbancy index, a_M, (the ratio of the absorbancy to the product of the thickness in centimeters and the concentration in moles per liter) and $\log_{10} a_M$. Changes in spectral transmittancy with changes in temperature were investigated. They were found to be small above 235 millimicrons but large from 215 to 235 mμ.

The NBS investigation also included a study of the effects of storing the solutions for periods up to eight years. The results showed that solutions stored in ordinary storeroom glass bottles are reasonably stable for about five years. The greatest changes occur below 260 mμ. For precision work it is recommended that the solutions be prepared from chemicals of the highest purity possible and that they be freshly prepared every six months.

For calibration data and further technical details, see An alkaline solution of potassium chromate as a transmittancy standard in the ultraviolet, *by Geraldine W. Haupt, J. Research NBS* **48**, *414 (1952) RP 2331.*

Exterior of the National Bureau of Standards Radio Broadcasting Station WWV, Beltsville, Maryland. From this station standard radio frequencies of 2.5, 5, 10, 15, 20, and 25 Mc are transmitted continuously, night and day, with accuracies of two parts in 100 million. Two standard audio frequencies, 600 and 440 cycles, are broadcast on all radio carrier frequencies, starting with 600 cycles on the hour, interrupted one minute, followed by 440 cycles for four minutes interrupted one minute. The telephone poles support the antenna system, from which the signals are transmitted to all parts of the world.

ACCOMPANYING the maintenance of the Nation's primary standard of frequency is a continuing investigation by the National Bureau of Standards of methods for improving the constancy and reliability of the standard. Some modifications incorporated within the last few years include the use of resonator crystals to sustain the accuracy of the standard, more sensitive and reliable temperature controls, and precise clock mechanisms to monitor time signals. The use of new and improved components has resulted in a reduction in the number of replacement parts and represents a considerable saving of time normally required for preventive maintenance procedures.

The NBS primary standard of frequency is the foundation upon which are based all time and frequency transmissions from the Bureau's radio broadcasting stations WWV in Beltsville, Maryland, and WWVH, Maui, Hawaii. From these stations, standard radio frequencies of 2.5, 5, 10, 15, 20, and 25 Mc are transmitted continuously, night and day, with accuracies of 2 parts in 100 million. Two standard audio frequencies, 600 and 440 cycles (the standard musical pitch A above middle C) are broadcast on all of the radio carrier frequencies; every five minutes they are interrupted for intervals of 1 minute. A pulse of 0.005-second duration occurs on each carrier frequency at intervals of 1 second. The time intervals, as transmitted, are accurate within $\pm$(two parts in 10^8+1 microsecond). An announcement of radio propagation conditions, pertinent only to transmission paths in the North Atlantic area, is broadcast in code on each of the standard radio frequencies.

The National Bureau of Standards primary standard of frequency consists of nine crystal-controlled oscillators and eight quartz crystal resonators. Three of the oscillators are located at the Beltsville installation of WWV—one acting as the main oscillator for all of the transmitters, the second as the standby, and the third as a spare. The remaining six oscillators and the eight quartz crystal resonators are maintained at the Bureau's Washington laboratories. All of the crystal-controlled oscillators are kept in continuous operation and the best ones—those having the least amount of deviation from 100 kc for the immediately preceding six months period or longer—are the units from which the standard frequency is determined.

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NBS PRIMARY STANDARD OF FREQUENCY

The oscillators are controlled by specially made GT-cut quartz crystals; the resonant frequency of each crystal is 100 kc. In an investigation of the crystals, it has been observed that generally their performance curves (frequency vs amplitude) have a flat region within which the crystal frequency is relatively constant. When the driving current reaches a value of about 150 microamperes, the frequency decreases sharply. In view of this fact, the driving current applied to the crystal units of the newer NBS oscillators is less than 100 microamperes. A decided improvement in performance occurs and is especially evident when the newer oscillators are compared with the older oscillators with driving currents of over 500 microamperes. Increased short-time stability and over-all reliability has also been achieved.

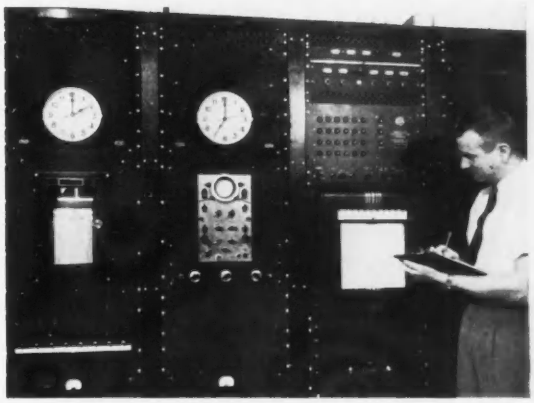
The eight resonator crystals have been part of the frequency standard for about one and a half years. Each resonator's frequency is used in the analysis of the accuracy and constancy of the other nine oscillators. All eight crystals, each also with a resonant frequency of 100 kc, are installed in a single temperature-controlled oven. They do not incorporate additional components such as tubes, resistors, or capacitors. They are not driven continuously but are used only once a day as part of a balanced-bridge network for comparison with one of the standard oscillators. Furthermore, the current driving the crystals is only ten microamperes.

Once a day the value of each resonator crystal and each standard oscillator is determined. First, a precision variable oscillator is adjusted to the frequency of one of the resonators. The variable oscillator is then compared with one of the standard oscillators, and the beat or difference frequency is counted on an electronic frequency counter with a precision of the order of parts in 10^{10}. The variable oscillator is readjusted to the second resonator crystal and again compared with the same standard oscillator. The difference frequency between these two oscillators is again recorded. This procedure is continued until data are available indicating the amount of frequency deviation present between the standard oscillator and each of the resonator crystals. One of the remaining eight oscillators is used as a reference against which all of the other oscillators are compared. Thus, data are available for precise determination of any changes, relative to the system, which may occur in any oscillator or resonator in the system.

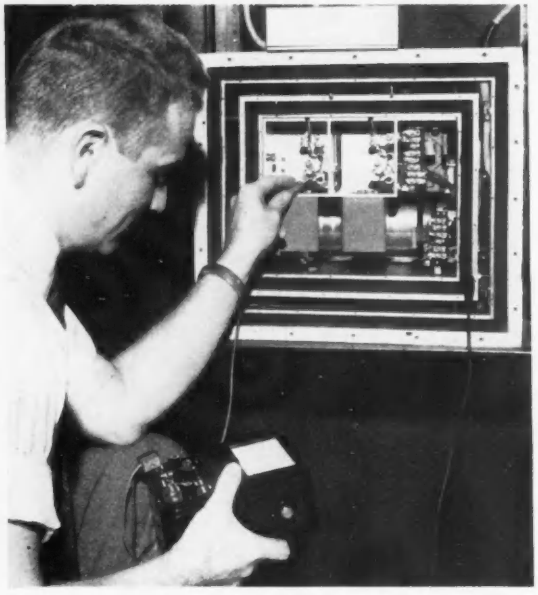
The reference oscillator is also instrumental in obtaining a continuous record of the frequencies of the three standard oscillators at the WWV installation. Automatically the main, standby, and spare oscillators are successively switched at preset intervals to a low power VHF transmitter. The signals are beamed to the NBS laboratory in Washington, and the received signals are compared with the signals derived from the reference oscillator.

A more precise and reliable temperature control of the ovens enclosing the oscillators has been developed. The oven essentially consists of four concentric cubical chambers: the center chamber holds the oscillator unit, and the space of the next and outer chamber is filled with felt insulation. An air-chamber containing mat heaters separates the insulated chambers. The outer heater, designed for coarse temperature control, is controlled by a simple mercury thermostat.

Control of the inner heater, designed to respond to very small changes in temperature, is achieved by use of a network in which the heater element is part of the sensing circuit. In effect, one pair of arms of a resistance bridge is made up of wire with a high temperature coefficient and the other pair of wire of negligible temperature coefficient. Current through both pairs of wires supplies the necessary heat. An oscillatory circuit composed of the bridge connected between the input and output of a high gain amplifier—essentially a



Frequency monitoring equipment. Two racks at left contain spark chronograph and chronoscope used to measure time differences between any two standard-controlled clocks to precision of ±0.02 millisecond. Third rack from left contains automatic beat frequency recorder for intercomparing primary frequency standards. Automatic switching unit (top panel) connects each of six oscillators sequentially to dual electronic frequency counter (next panel below). Recording frequency meter with sensitivity of ±1 part in 10^{10} provides permanent record of frequency differences between standards. Remainder of rack contains power supplies, proportional voltage generator that converts count summation to recorded voltage, and dual frequency multiplier and demodulator providing difference frequencies between oscillators.



Temperature control compartment containing crystal and temperature-sensitive components of one of nine crystal-controlled oscillators of NBS primary standard of frequency. Compartment is made up of four concentric cubical chambers. Quartz-crystal unit of osillator is contained in electronically controlled cylindrical oven (at back of center chamber). A special resistance bridge-feedback amplifier arrangement maintains temperature constant to 0.001 deg C. Unit on top of oven contains vacuum-tube amplifier portion of oscillator.

feedback loop—controls the temperature. When the temperature is near the desired value—the bridge is slightly unbalanced—the amplifier is in a stable condition. As the outer temperature of the oven decreases, the bridge becomes further unbalanced and the amplitude of the output oscillations increases so as to supply more current to the bridge wires and, consequently, more heat to the oven. This condition continues until the temperature regains the operating assigned value. Under normal room conditions, the temperature is controlled to better than 0.001 degree C.

The temperature-control oven for the eight resonator crystal units is constructed with six concentric cubical chambers. All eight crystals are enclosed in the one oven, and the temperature control is achieved with mercury thermostats connected to both inner and outer heaters. Inner temperature variation is less than 0.005 degree C for average variations in room temperature. The standard oscillators at the NBS transmitting station in Beltsville are installed in a room approximately six feet on a side built about 25 feet below the ground. The complete room is temperature and humidity controlled.

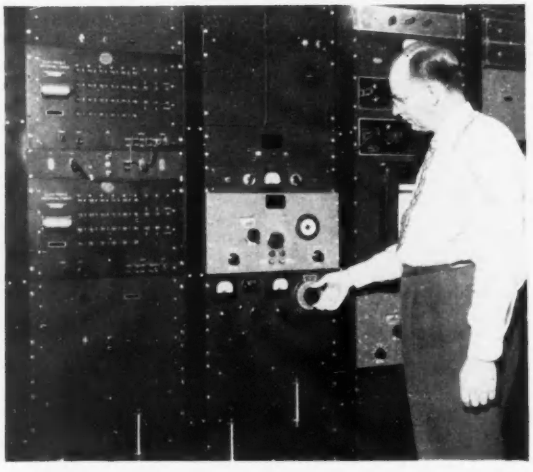
Each of the frequency standards is equipped with individual power supplies and includes improved filters to permit better regulation and control. The supplies all have plate and filament batteries that are continuously float-charged, and in the event of an a-c power failure they can carry the full load for many hours.

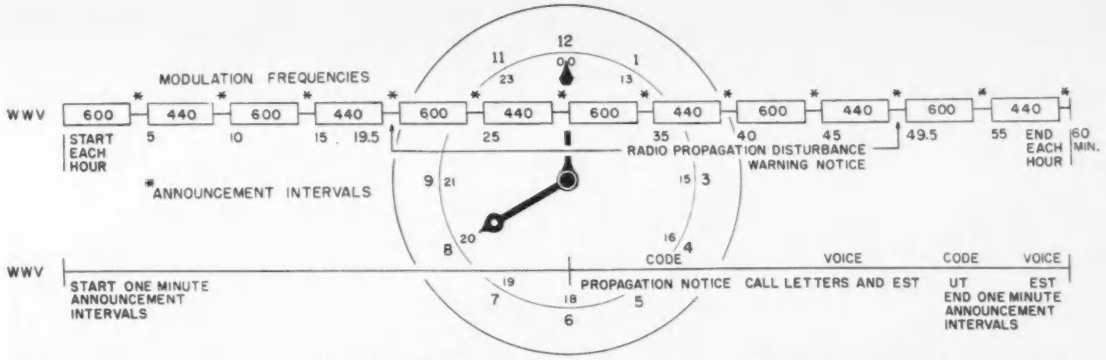
In order to monitor accurately the time signals generated by the frequency standard, one of the NBS standard oscillators is used to drive a synchronous clock. The 100 kc output of each oscillator is electronically divided to a frequency suitable for driving a spark chronograph and chronoscope. The instruments are designed so that the driving oscillator may be compared with the time signals of the other five oscillators in the Washington laboratory and those at the WWV installation to differences as small as 20 millionths of a second.

The time differences or variations in each clock are reported each day to the U. S. Naval Observatory and are used in evaluation of the mean solar time. The Observatory issues weekly corrections to the WWV signals with reference to mean solar time. Quarterly corrections for the slight deviations in absolute time and frequency as broadcast by WWV are also available from the Bureau.

One of the principal uses of the WWV transmission of standard frequencies is that of calibration of precision oscillators. The system commonly employed is demonstrated by the manner in which the WWVH (Hawaii) transmissions are synchronized with those from WWV. Three oscillators are used to give accurate results. One oscillator unit is adjusted to one of the standard frequency transmissions from WWV. Each of the other two oscillators is compared with the

NBS primary resonator frequency standard. Rack at right contains temperature controlled oven (constant to 0.001 deg C) in which resonator crystals are located (panel with two thermometers). Rack also includes special bridge for comparing oscillator with quartz resonator crystals, precision adjustable oscillator (operator is shown making adjustment), power supplies, and high gain, narrow band receiver. Rack at left contains dual electronic counters for counting frequency differences between oscillators. Also included is additional temperature controlled compartment for use in measuring experimental resonator crystals.





Schematic diagram showing services offered by NBS Radio Broadcasting Station WWV. At start of each hour, a 600-cycle tone is heard for four minutes. This is interrupted by a 1-minute announcement period in which Eastern Standard Time is announced in voice and Universal Time in code. At conclusion of announcement period, a 440-cycle tone is transmitted for four minutes. Announcements are repeated for new time and then followed by 4-minute 600-cycle tone. A pulse of 0.005-second duration at intervals of one second is broadcast simultaneously with audio notes. At 19½ and 49½ minutes past the hour, radio propagation disturbance warnings are transmitted in code.

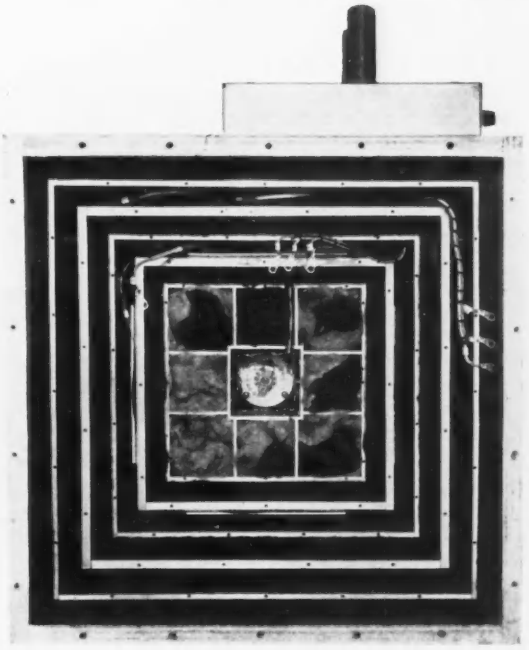
first, and the difference in frequency between them is measured. A better average of the deviation from the WWV transmissions is achieved by this method than the one which would be possible if only one oscillator was involved.

One of the major continuing projects of the Bureau's frequency standard laboratory is the development of more precise quartz oscillators. Another is the investigation of the use of atomic- and molecular-resonance standards as a means for obtaining higher accuracies. Reference to such invariant standards would greatly simplify the maintenance of precise frequency and time standards.

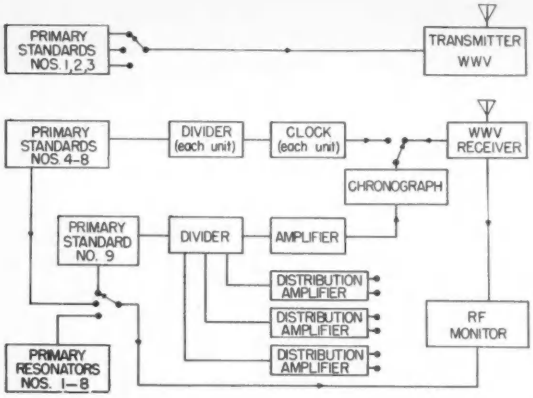
NBS Automatic Announcing System

Accompanying the improvements in the NBS Standard of Frequency is a complete change in the method of reproducing the announcements transmitted by Radio Station WWV. Formerly, the hour, minute, and propagation announcements were sent in code or voice from separate machines. The complete voice message was recorded on magnetic tape, and no portion was used twice during the day. The present method utilizes motion picture film sound track, a photoelectric scanning system, synthesis of the message, and electronic amplification as a means for providing voice and code announcements.

The new system of making WWV announcements, specially developed to NBS specifications by the Audichron Company of Atlanta, Georgia, is similar to equipment used in many municipal telephone exchanges that include time announcements as part of their service. The NBS system is designed to announce "Station WWV. When the tone returns, Eastern Standard Time is ————". It also gives the Universal Time in code and, once every half hour, the radio propagation forecast for the next 12 hours. The sound is reproduced by scanning photographic film with a narrow beam of light. The light passing through the film is reflected onto a photoelectric cell, and the electrical impulses thus produced are amplified to supply the speech input equipment. The voice announcement films are mounted on three drums which are actually cylindrical mirrors: one contains the preliminary announcements,



Temperature control compartment containing resonator crystals of primary standard of frequency. Oven is made up of six concentric cubical chambers. Partitioned center chamber contains eight quartz-crystal resonators and switch for connecting each crystal to external measuring circuit. Box on top of oven contains heater controls and power-supply line filters.



Block diagram of NBS primary standard of frequency.

another the hours, and a third the minutes. The code machine has three similarly mounted films that contain the hours, minutes, and the propagation information. From these records, the machine "builds up" or composes the complete message in the proper sequence. An identical announcing system is provided for standby operation in case of failure of the main unit.

Each set of three drums is mounted on a common axis. Above each set of drums is a carriage supporting a photoelectric cell and light source. The surface of each drum is highly polished, so that the image of an exciter filament lamp, focused on the sound striations on the film, is reflected upon the photocell contained in the scanning head. The strips of motion picture film are wound spirally upon the cylindrical mirrors, which revolve at 30 revolutions per minute. Synchronous motors drive the drums and derive their operating voltages directly from the NBS frequency standard. Thus the drum revolutions are always in step with the signals transmitted by WWV, which precisely synchronizes the announcements with the tone-break periods.

The scanning head is made to follow the film strip by a cam follower running on a spiral groove milled into the surface of the main cam. The spiral groove is endless, but the lead at one end is cut at a smaller angle than the rest of the cam so that the carriage remains nearly stationary for a few seconds at the beginning of each sweep cycle and then scans in both directions. A complete cycle of the machine is exactly 10 seconds.

Each strip of film has one part of a time announcement recorded on it. Because WWV transmits time announcements every five minutes (288 different announcements per day), the film carrying the minutes needs only the words 5, 10, 20, etc. The minute drums are wound with 24 strips of film, two for each 5-minute interval in the hour. The first 2 strips have no sound photographed on them while the last 2 strips carry "fifty-five." The first strip on the hour film is blank, and the last reads "twelve." The preliminary voice announcement, "Station WWV . . . . . ," is recorded on a single strip. The same photocell responds to a tape containing the AM and PM announcements, which are selected by a solenoid-operated shutter. The code films containing the propagation notices are scanned by a photocell which can be displaced manually to the proper film strip with the latest information. This operation is performed every 6 hours.

Suppose, for example, that the next announcement will be 3:45 PM EST. The scanning head is at one end of the carriage. At 3:44:40 the photocell begins to scan the film containing the preliminary announcement. At 3:44:41 the photocell responds to "Radio Station WWV. When the tone returns, Eastern Standard Time is ———." By this time (3:44:46) the scanning head has reached the film carrying the hour, and the word "three" is fed into the amplifying system. The operation continues so as to carry the scanning head to the minute film so that "forty-five" can be heard. In the proper time sequence, the output from the film containing "PM" is also put in the system. Thus, by 3:44:50, the hour, minute, and meridian position have been announced. Meanwhile, the scanning head on the code machine has reached a position so that at 3:44:50.5, the Universal Time is broadcast in code in the same manner as was the voice announcement. By 3:44:55.5, the code announcement is concluded, and the carriage above the voice drums is in a position to reproduce "3:45 PM." Both the code and voice announcements are completed from about two- to three-quarters of a second before 3:45:00.

At 19½ and 49½ minutes past the hour, a radio propagation notice becomes part of the code announcement. This announcement—either "N" (normal), "U" (unsettled), or "W" (disturbed) and a number (3 to 7 signifying poor to good propagation conditions for the next 12 hours)—begins exactly at 3:19:30 and 3:49:30, for example, and is followed by the voice and code announcements described above.

The scanning-revolving mechanisms are arranged so that when 60 minutes have expired, the hour drum is advanced to the film containing the next hour. The photocell responds to the reflected light at all times. An electronic alarm system is available that utilizes this between-announcement scanning voltage. If the voltage is not of a predetermined value, the alarm will be set off and the announcement system will be automatically switched to the standby unit.

Besides being completely automatic, the NBS announcing system makes it possible to broadcast information more reliably than with tape methods. A further refinement planned for the near future is the incorporation of means for operating the synchronous motors directly from commercial power lines. Frequency control of the voltage supplying the synchronous motors will be achieved by phasing networks that will keep the time announcements exactly in step with the frequency standard.

For additional information concerning NBS time and frequency transmissions, see Standard frequencies and time signals from WWV and WWVH, *NBS letter circular. LC 1009. For information on accurate monitoring of time signals, see* New spark chronograph and chronoscope, *NBS Technical News Bulletin, Vol.* **35,** *1, 14 (Jan. 1951).*

Live Loads on Building Floors

DESIGN requirements for structural elements in buildings depend on knowledge of the loads to which these elements may be subjected. These loads include dead loads, live loads, snow loads, wind pressures, and earthquake forces. Dead loads consist chiefly of the weight of the building itself, while live loads consist of the variable loads due to human occupancy, e. g., the weight of equipment, furniture, other movable goods or materials, and human beings. Because of the meager information available on live loads on floors in typical occupancies, a study of such loads in business, industrial, and storage occupancies was undertaken in 1947 by the National Bureau of Standards in cooperation with the Public Buildings Service. While the study was necessarily limited to a few buildings, the data obtained were quite complete, containing sufficient detail for a comparative study of the variation in loading on different parts of the same floor. The results obtained, together with summaries of surveys made some years earlier, should be of considerable interest to designers of buildings and to building officials.

Building codes require that all buildings shall be designed to carry their loads safely and give a list of minimum assumed live loads for the more common occupancies. Actual loading may differ from the values given, but in practice most buildings are probably designed at the minimum values. It is thus important that these values represent the worst conditions for which it is reasonable to provide.

In design practice, allowance for live loads is made by assuming loads for various classes of occupancy. The live-load values which have been accepted in various building codes show good agreement even though they are based on relatively little data; but it is difficult to estimate the validity of the figures used. The expense and trouble of actually weighing materials and equipment in buildings probably account for the dearth of data.

Since there have been few cases of building collapse due to incorrect load assumptions, there has been no compelling reason for intensive investigations of loads. Now, with new materials constantly coming into use and with the increasing urgency for the conservation of materials, the problem of what assumption the designer shall make for a given live load has become important.

One of the earliest studies on the weight of building contents was made by the Department of Commerce Building Code Committee, which prepared a report in 1925 on loads in dwellings, hotels, and other residential occupancies, hospitals, schools, office buildings, library stack rooms, and manufacturing buildings of various kinds. In 1946 the Public Buildings Service announced the results of an investigation of loadings of two Federal office buildings in Washington. In 1945 the National Bureau of Standards published a report containing the recommendations of the Sectional Committee on Building Code Requirements for Minimum Design Loads in Buildings—A 58 of the American Standards Association. While this report contained no original data, it did give a recommended assumption for office loads of 80 lb/ft^2, an increase from 50 lb/ft^2 given in the 1925 report.

In the PBS–NBS survey, actual weights of equipment and furniture were obtained for two department stores, two mattress factories, two clothing factories, two furniture factories, two printing establishments, and two

Left: **Segment of floor plan of a Washington, D. C., department store surveyed in the PBS–NBS investigation of live loads for mercantile occupancy.** ***Right:*** **Photograph of aisles of same department store, showing human load. The live load was determined as follows: (1) weights of typical items of furniture and contents were established by weighing representative pieces as normally filled; (2) persons found in a given area at the time of the survey were assumed to weigh 150 pounds each; (3) some items, such as display cases and built-in construction that could not be weighed, were measured and the weights computed.**

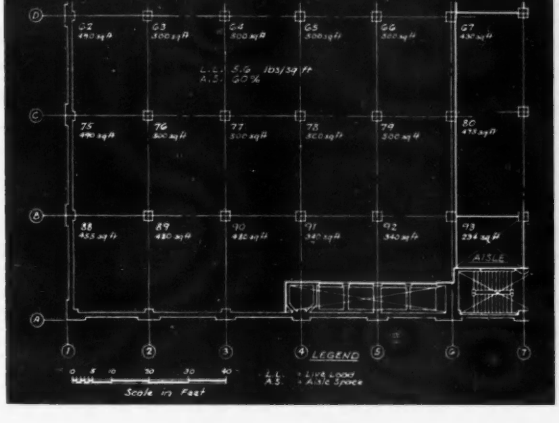


TABLE 1. *Live floor loading*

Type of occupancy	General code minimum	PBS-NBS survey data	
		Median [a]	Maximum [a]
	lb/ft²	*lb/ft²*	*lb/ft²*
Residences	40		
Office buildings	50 to 80		
Department stores	75 to 125		
Store No. 1		42	61
Store No. 2		35	67
Assemblies	50 to 100		
Light manufacturing	75 to 125		
Mattress factory No. 1		13	41
Mattress factory No. 2		22	60
Men's clothing factory		13	47
Dress factory		7	60
Furniture factory No. 1		17	98
Furniture factory No. 2		8	120
Heavy manufacturing	125 to 150		
Newspaper plant		18	93
Printing plant		52	168
Light storage	120 to 125		
Heavy storage	250		
Warehouse No. 1		82	257
Warehouse No. 2		33	304

[a] Not including partitions or radiators, but including a factor for maximum human load.

warehouses. All movable equipment was weighed or estimated, and an allowance was made for human load. Fixed pieces of equipment, such as radiators, were not considered part of the live load. Maximum measured live loads obtained in the survey, together with the median loads, are listed in table 1. An idea of the extent of the variations in loading in a single occupancy may be obtained by comparison of the last two columns of this table. In the following section, brief discussions are given of typical occupancies, with techniques of obtaining the data, and typical building code requirements.

Residential Occupancy. Most building codes permit a minimum assumed live load of 50 lb/ft² for residential occupancy. There are occasional instances where codes permit a figure of 30 lb/ft² to be used for upper floors of single-family dwellings, and the same figure has been advocated by some authorities for general use throughout dwellings.

Various reasons have been advanced for the selection of 40 lb/ft² for this occupancy. Some authorities have pointed out that it takes care of maximum possible loading when persons are assembled at teas, funerals, and other occasions. Others believe that the figure was not intended to represent the actual load in a dwelling but was selected because a wood-joist floor designed for a lesser load was generally considered too limber for the comfort of the occupants. From the latter point of view, the use of 40 lb/ft² is thus an indirect method of obtaining the desired rigidity in wood-joisted construction. Although there have been numerous estimates and assumptions made as to live loads in this occupancy, no published figures obtained from weighing the contents of dwellings have been found.

Business Occupancy. The minimum assumed live loads permitted for business buildings by building codes vary from 50 to 80 lb/ft². More attention has been given to loading in office buildings than has been given to loading in any other occupancy.

Most office loading is in a zone within three feet of the walls, but the designer must allow for library shelves and double filing cabinets not near partitions and for the condition where furniture is collected in the middle of the room during cleaning or moving. Live loads are found to be lighter near the exterior walls of the building; filing cases, cabinets, safes, bookcases, and bins are usually located against blank interior walls. In earlier studies, several instances were found where two adjacent floor bays supported average loads of 25 lb/ft² or more, but in no case were two adjacent bays found loaded in excess of an average of 40 lb/ft². Weight of employees was found to add from 0.9 to 1.75 lb/ft² of floor area.

Mercantile Occupancy. The term "mercantile occupancy" is not used in all codes; but it covers such occupancies as stores, shops, salesrooms, and markets. For these the permissible minimum design live load given in building codes ranges from 75 to 125 lb/ft².

The PBS-NBS survey of two department stores was made when few people were present. To account for the large human load during special sales or at Christmas, there is given, in addition to the measured load, a load "with aisles crowded" which is an increase of 60 lb/ft² for aisle space. The maximum floor loadings were 66.7 lb/ft² in the service area on the first floor of a Washington, D. C., store and 60.7 lb/ft² in the phonograph-record department of a New York City store.

Assembly Occupancy. Assembly occupancy includes theaters, dance halls, auditoriums, churches, and schools. Building codes recommended for national or regional use and building code standards give permissible minimum live loads of from 50 to 60 lb/ft² for orchestra floors of theaters and for floors of assembly halls with fixed seats, and 100 lb/ft² for those with movable seats. Dance halls are assigned 100 to 120 lb/ft². School classrooms with fixed seats are required to be designed for 40 to 60 lb/ft²; and those with movable seats, from 40 to 100 lb/ft².

Industrial Occupancy. The industrial classification contains widely varying examples of floor loading since it includes occupancies involved in manufacturing, fabrication, and assembly of all kinds of industrial products. Recommended building codes give minimum design loads of from 75 to 125 lb/ft² for light manufacturing. For heavy manufacturing some give values of from 125 to 150 lb/ft², and others do not assign any particular value.

In the PBS-NBS survey, a number of different methods were employed to determine the loading. In some cases, all material found in a given area was weighed; in others, typical items were weighed and the total weight computed. Where neither of these methods seemed practicable, weights were obtained from the plant manager, manufacturer, or catalogs. In some instances, equipment was measured and its weight calculated from known or assumed densities. Although there is a tendency to place heavy machinery on ground floors or on special foundations reaching to the ground, some machines encountered in the survey were on upper floors. In such cases, the machine weights were

averaged over areas considerably greater than those immediately adjacent to the machines.

Storage Occupancy. Live loads on warehouse floors vary widely. Building codes give permissible minimum design load figures for light and heavy storage. In the case of light storage, the range is narrow, from 120 to 125 lb/ft^2, while for heavy storage a minimum value of 250 lb/ft^2 is customary. For the two warehouses surveyed, loading was determined by notation of weights marked on barrels and other containers and allowance of 150 lb each for persons normally found in a given area.

Variation in Loading. The data show fairly large differences in loading on different areas within the same occupancy. In some cases, such as those involving libraries or storage rooms in office buildings, it may be possible to anticipate and to provide for unusually heavy loads. In other occupancies, as in department stores, there may be frequent shifts of goods from one part of a floor to another or from floor to floor in response to changes in sales policy, seasonal demands, or other considerations, with the result that unit loads on given areas may change several hundred percent.

It is apparent that there is a problem in the selection of a representative minimum unit-load value for each typical occupancy and in the determination of a reasonable reduced unit-load value for a large area supported by a given structural member. In the case of a small area, the total load will be the minimum unit load multiplied by the area. For larger areas, however, a reduction is considered permissible for loads carried by columns and girders, and sometimes beams, since such members seldom, if ever, are loaded to the extent of the unit live load multiplied by the total area supported.

Discussion. The data obtained in the surveys afford code writers an opportunity to correlate code requirements with specific examples; the more extensive and detailed such surveys are for a given occupancy, the firmer are the conclusions to be drawn from them. The data represent not the most severe loading possible but the actual average loading in each case on a given area of a given occupancy. It appears that a large percentage of the floor area in most occupancies is much less heavily loaded than the most heavily loaded bay. This suggests possible further economies in the design of members carrying large floor areas. However, the data available are still small in quantity, and there are conditions of local load concentrations that must not be overlooked. With additional information gained from further surveys, it should be possible to answer more definitely certain questions, such as how representative are the minimum live-load assumptions now given in building codes recommended for national or regional use.

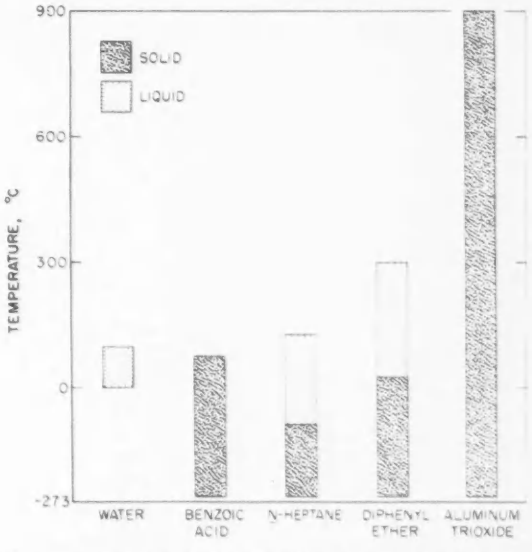
For further technical details, see Live loads on floors in buildings, *National Bureau of Standards Building Materials and Structures Report BMS133, by J. W. Dunham of PBS and G. N. Brekke and G. N. Thompson of NBS, available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at a cost of 20 cents.*

Heat-Capacity Standards

WITH THE EXTENSION of heat measurements toward the extremes of the temperature scale, NBS is developing new standards of heat capacity for use at temperatures where water, the present standard substance, cannot conveniently be employed. Special samples of three materials—benzoic acid, *n*-heptane, and aluminum trioxide—have already been prepared and their heat capacities determined over most of the useful temperature range, and a limited number of these samples are now available to laboratories equipped to make very precise measurements of heat capacity.

Because water is universally available in high purity, it has been used as a standard for heat-capacity measurements since the early development of calorimetry. However, recent developments in such fields as low-temperature physics, nuclear engineering, and jet propulsion have necessitated extension of heat measurements to both very high and very low temperatures. Although water has served admirably as a heat-capacity standard in the range from 0° to 100° C, it is not well suited to use outside this range. Below 0° C its large expansion on freezing makes it too hazardous for many calorimeters, while above 100° C its increasing vapor pressure usually makes it impractical for use.

This problem was considered in 1949 by the Fourth Conference on Calorimetry, an informal meeting of representatives from various American laboratories interested in precision calorimetric measurements. Recognizing the need for standards which could be used over a wide temperature range to compare precision calorimeters in different laboratories, the Conference recommended benzoic acid, *n*-heptane, and aluminum oxide in addition to water for use as heat-capacity standards.



Comparison of useful range of water as heat-capacity standard with useful ranges of new NBS standards.

The Bureau then undertook the task of preparing and distributing special samples of the three compounds.

Benzoic acid was fractionally crystallized at the Bureau to a purity of 99.997 mole percent, and *n*-heptane was both fractionally distilled and crystallized to about the same purity. The aluminum oxide samples were prepared from commercially available synthetic sapphire (corundum). D. C. Ginnings and G. T. Furukawa of the NBS thermodynamics laboratory measured the heat capacities of these materials over the range from −259° to +900° C, which includes most useful temperatures. Except at the extremes of the range, the results are believed to be accurate to about 0.1 or 0.2 percent.

In general, benzoic acid will be useful as a standard when a solid is needed at temperatures below 80° C. *N*-heptane can be used effectively up to about 130° C; it provides a liquid standard which can be distilled in and out of a calorimeter and which does not expand on freezing (at −90.6° C). Aluminum oxide is unique among these materials—it can serve as a practical standard in the entire temperature range up to 900° C; and as soon as accurate measurements of its heat capacity are available at higher temperatures, it should be usable up to 2,000° C.

In addition to water, benzoic acid, *n*-heptane, and aluminum oxide, a fifth material—diphenyl ether—has been suggested as a heat-capacity standard. Advantages of this substance are its chemical inertness, relatively high boiling point, and ease of purification. A very pure sample of diphenyl ether has recently been prepared at NBS by fractional crystallization, and its heat capacity has been measured up to 300° C.

In the past there has been considerable discrepancy between calorimetric results obtained by various investigators using different types of apparatus, particularly at high temperatures. It is hoped that the heat-capacity standards under development at NBS will provide a means for comparison of measurements made in different laboratories under different experimental conditions. Such standards should also make it possible for workers in calorimetry to check the absolute accuracy of their results over a much broader temperature range than heretofore and to calibrate accurately their apparatus in the absence of other more elaborate means of calibration.

Further information regarding the heat-capacity standards may be obtained from Dr. D. C. Ginnings, National Bureau of Standards, Washington 25, D. C.

Automotive Antifreezes

INTENDED primarily for the average automobile owner, the newly issued Circular 506, *Automotive Antifreezes*, should also prove helpful to manufacturers and businessmen interested in the field of antifreeze production. This complete revision of Circular 474 discusses such questions as when antifreezes should be installed, what strength should be used, and what kind of antifreeze is best suited to the service involved. In addition, it gives information concerning pertinent physical properties and service performance of the major categories of antifreezes. One section explains how the automobile should be prepared for antifreeze, and another describes simple means for distinguishing the different types of antifreezes and for determining the protection.

This 31-page publication summarizes in text and 17 illustrative figures the results of extensive tests at the Bureau as well as the work of other investigators. NBS Circular 506 can be obtained for 15 cents from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Publications of the National Bureau of Standards

Periodicals

Journal of Research of the National Bureau of Standards, volume 49, number 6, December 1952 (RP2372 to RP2379, incl.). Annual subscription, $5.50.

Journal of Research of the National Bureau of Standards, volume 48, Title page, corrections, and contents, January to June 1952 (RP2279 to RP2335, incl.). 10 cents.

Technical News Bulletin, volume 36, number 12, December 1952, 10 cents. Annual subscription, $1.00.

CRPL–D100. Basic Radio Propagation Predictions for March 1953. Three months in advance. Issued December 1952. 10 cents. Annual subscription, $1.00.

Research Papers

Reprints from Journal of Research, volume **49**, *No. 5, November 1952*

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Publications in Other Journals

The probability distribution of the phase of the resultant vector sum of a constant vector plus a Rayleigh distributed vector. Kenneth A. Norton, Edna L. Schultz, and Helen Yarbrough. J. App. Phys. (57 East Fifty-fifth Street, New York 22, N. Y.) **23**, No. 1, 137 (January 1952).

Gapless coverage in air-to-ground communications at frequencies above 50 mc. Kenneth A. Norton and Philip L. Rice. Proc. IRE (1 East Seventy-ninth Street, New York 21, N. Y.) **40**, No. 4, 470 (April 1952).

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